# Top, Higgs, Diboson and Electroweak Fit to the

### **Standard Model Effective Field Theory**

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Based on 2012.02779 J. Ellis, MM, K. Mimasu, V. Sanz, T. You



**Higgs and Effective Field Theory 2021** 

### The Standard Model Effective Field Theory

Powerful tool for capturing deviations from the SM and performing indirect searches for new physics.

**Model independent:** assume the BSM physics is heavy

 $E << \Lambda$ 

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{i} \frac{C_{i}}{\Lambda^{2}} \mathcal{O}_{i} + \dots$$

We restrict to dimension-6 operators.

## The Standard Model Effective Field Theory

#### Warsaw basis [1008.4884 Grzadkowski et. al]

X <sup>3</sup>			$H^6$ and $H^4D^2$	$\psi^2 H^3$		
$O_G$	$f^{ABC}G^{A\nu}_{\mu}G^{B\rho}_{\nu}G^{C\mu}_{\rho}$	$\mathcal{O}_{H}$	$(H^{\dagger}H)^3$	$\mathcal{O}_{eH}$	$(H^{\dagger}H)(\bar{l}_{p}e_{r}H)$	
$O_{\tilde{G}}$	$f^{ABC} \widetilde{G}^{A\nu}_{\mu} G^{B\rho}_{\nu} G^{C\mu}_{\rho}$	$\mathcal{O}_{H\square}$	$(H^{\dagger}H)\square(H^{\dagger}H)$	$\mathcal{O}_{uH}$	$(H^{\dagger}H)(\bar{q}_{p}u_{r}\tilde{H})$	
$O_w$	$\varepsilon^{IJK}W^{\dot{I}\nu}_{\mu}W^{J\rho}_{\nu}W^{K\mu}_{\rho}$	$\mathcal{O}_{HD}$	$\left(H^{\dagger}D^{\mu}H\right)^{*}\left(H^{\dagger}D_{\mu}H\right)$	$\mathcal{O}_{_{dH}}$	$(H^{\dagger}H)(\bar{q}_p d_r H)$	
$\mathcal{O}_{\overline{W}}$	$\varepsilon^{IJK} \widetilde{W}^{I\nu}_{\mu} W^{J\rho}_{\nu} W^{K\mu}_{\rho}$					
	$X^2H^2$	$\psi^2 X H$		$\psi^2 H^2 D$		
$\mathcal{O}_{HG}$	$H^{\dagger}H  G^A_{\mu\nu} G^{A\mu\nu}$	${\cal O}_{eW}$	$(\bar{l}_p \sigma^{\mu\nu} e_r) \tau^I H W^I_{\mu\nu}$	$\mathcal{O}_{Hl}^{(1)}$	$(H^{\dagger}i \overset{\leftrightarrow}{D}_{\mu} H)(\bar{l}_{p} \gamma^{\mu} l_{r})$	
$O_{H\tilde{G}}$	$H^{\dagger}H\widetilde{G}^{A}_{\mu u}G^{A\mu u}$	${\cal O}_{eB}$	$(\bar{l}_p \sigma^{\mu\nu} e_r) H B_{\mu\nu}$	$\mathcal{O}_{Hl}^{(3)}$	$(H^{\dagger}i D_{\mu}^{I} H)(\bar{l}_{p}\tau^{I}\gamma^{\mu}l_{r})$	
$O_{HW}$	$H^{\dagger}H W^{I}_{\mu u}W^{I\mu u}$	$\mathcal{O}_{uG}$	$(\bar{q}_p \sigma^{\mu\nu} T^A u_r) \tilde{H} G^A_{\mu\nu}$	$\mathcal{O}_{He}$	$(H^{\dagger}i D_{\mu} H)(\bar{e}_p \gamma^{\mu} e_r)$	
$\mathcal{O}_{H\widetilde{W}}$	$H^{\dagger}H \widetilde{W}^{I}_{\mu\nu}W^{I\mu\nu}$	$\mathcal{O}_{uW}$	$(\bar{q}_p \sigma^{\mu\nu} u_r) \tau^I \tilde{H} W^I_{\mu\nu}$	$\mathcal{O}_{Hq}^{(1)}$	$(H^{\dagger}i D_{\mu} H)(\bar{q}_p \gamma^{\mu} q_r)$	
$\mathcal{O}_{HB}$	$H^{\dagger}HB_{\mu u}B^{\mu u}$	${\cal O}_{uB}$	$(\bar{q}_p \sigma^{\mu\nu} u_r) \widetilde{H} B_{\mu\nu}$	$\mathcal{O}_{Hq}^{(3)}$	$(H^{\dagger}i D_{\underline{\mu}}^{I} H)(\bar{q}_{p} \tau^{I} \gamma^{\mu} q_{r})$	
$\mathcal{O}_{H\tilde{B}}$	$H^{\dagger}H\widetilde{B}_{\mu u}B^{\mu u}$	$\mathcal{O}_{dG}$	$(\bar{q}_p \sigma^{\mu\nu} T^A d_r) H G^A_{\mu\nu}$	$\mathcal{O}_{Hu}$	$(H^{\dagger}i \overset{\overleftarrow{D}}{D}_{\mu} H)(\bar{u}_p \gamma^{\mu} u_r)$	
$\mathcal{O}_{HWB}$	$H^{\dagger} \tau^{I} H W^{I}_{\mu\nu} B^{\mu\nu}$	$\mathcal{O}_{_{dW}}$	$(\bar{q}_p \sigma^{\mu\nu} d_r) \tau^I H W^I_{\mu\nu}$	$\mathcal{O}_{_{Hd}}$	$(H^{\dagger}i \overleftrightarrow{D}_{\mu} H) (\bar{d}_p \gamma^{\mu} d_r)$	
Ouwn	$H^{\dagger}\tau^{I}H\widetilde{W}^{I}_{\mu\nu}B^{\mu\nu}$	$\mathcal{O}_{dB}$	$(\bar{q}_{n}\sigma^{\mu\nu}d_{r})HB_{\mu\nu}$	$\mathcal{O}_{_{Hud}}$	$i(\widetilde{H}^{\dagger}D_{\mu}H)(\bar{u}_{p}\gamma^{\mu}d_{r})$	
- HWB	$\mu\nu$	415	(μ)		· - ····	
	$(\bar{L}L)(\bar{L}L)$		$(\bar{R}R)(\bar{R}R)$		$(\bar{L}L)(\bar{R}R)$	
$\mathcal{O}_{ll}$	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$	02	$(\bar{R}R)(\bar{R}R)$ $(\bar{e}_p\gamma_\mu e_r)(\bar{e}_s\gamma^\mu e_t)$	$\mathcal{O}_{le}$	$(\bar{L}L)(\bar{R}R)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{e}_s\gamma^\mu e_t)$	
$\mathcal{O}_{ll}$ $\mathcal{O}_{qq}^{(1)}$	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$ $(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$	$\mathcal{O}_{ee}$ $\mathcal{O}_{uu}$	$(\bar{R}R)(\bar{R}R)$ $(\bar{e}_p\gamma_\mu e_r)(\bar{e}_s\gamma^\mu e_t)$ $(\bar{u}_p\gamma_\mu u_r)(\bar{u}_s\gamma^\mu u_t)$	$\mathcal{O}_{le}$ $\mathcal{O}_{lu}$	$(\bar{L}L)(\bar{R}R)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{e}_s\gamma^\mu e_t)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{u}_s\gamma^\mu u_t)$	
$\mathcal{O}_{ll}$ $\mathcal{O}_{qq}^{(1)}$ $\mathcal{O}_{qq}^{(3)}$	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$ $(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$ $(\bar{q}_p\gamma_\mu \tau^I q_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$	$\mathcal{O}_{ee}$ $\mathcal{O}_{uu}$ $\mathcal{O}_{dd}$	$(\bar{R}R)(\bar{R}R)$ $(\bar{e}_p\gamma_\mu e_r)(\bar{e}_s\gamma^\mu e_t)$ $(\bar{u}_p\gamma_\mu u_r)(\bar{u}_s\gamma^\mu u_t)$ $(\bar{d}_p\gamma_\mu d_r)(\bar{d}_s\gamma^\mu d_t)$	$\mathcal{O}_{le}$ $\mathcal{O}_{lu}$ $\mathcal{O}_{ld}$	$(\bar{L}L)(\bar{R}R)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{e}_s\gamma^\mu e_t)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{u}_s\gamma^\mu u_t)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{d}_s\gamma^\mu d_t)$	
$\mathcal{O}_{ll}$ $\mathcal{O}_{qq}$ $\mathcal{O}_{qq}^{(1)}$ $\mathcal{O}_{lq}^{(3)}$	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$ $(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$ $(\bar{q}_p\gamma_\mu \tau^I q_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{q}_s\gamma^\mu q_t)$	$O_{ee}$ $O_{uu}$ $O_{dd}$ $O_{eu}$	$\begin{array}{c} (\bar{R}R)(\bar{R}R) \\ (\bar{e}_p \gamma_\mu e_r)(\bar{e}_s \gamma^\mu e_t) \\ (\bar{u}_p \gamma_\mu u_r)(\bar{u}_s \gamma^\mu u_t) \\ (\bar{d}_p \gamma_\mu d_r)(\bar{d}_s \gamma^\mu d_t) \\ (\bar{e}_p \gamma_\mu e_r)(\bar{u}_s \gamma^\mu u_t) \end{array}$	$egin{array}{c} \mathcal{O}_{le} \ \mathcal{O}_{lu} \ \mathcal{O}_{ld} \ \mathcal{O}_{qe} \end{array}$	$\begin{array}{c} (\bar{L}L)(\bar{R}R) \\ (\bar{l}_p \gamma_\mu l_r)(\bar{e}_s \gamma^\mu e_t) \\ (\bar{l}_p \gamma_\mu l_r)(\bar{u}_s \gamma^\mu u_t) \\ (\bar{l}_p \gamma_\mu l_r)(\bar{d}_s \gamma^\mu d_t) \\ (\bar{q}_p \gamma_\mu q_r)(\bar{e}_s \gamma^\mu e_t) \end{array}$	
$\begin{array}{ c c }\hline & & & \\ & $	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$ $(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$ $(\bar{q}_p\gamma_\mu \tau^I q_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$ $(\bar{l}_p\gamma_\mu \tau^I l_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$	$O_{ee}$ $O_{uu}$ $O_{dd}$ $O_{eu}$ $O_{ed}$	$(\bar{R}R)(\bar{R}R)$ $(\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{e}_{s}\gamma^{\mu}e_{t})$ $(\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{u}_{s}\gamma^{\mu}u_{t})$ $(\bar{d}_{p}\gamma_{\mu}d_{r})(\bar{d}_{s}\gamma^{\mu}d_{t})$ $(\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{u}_{s}\gamma^{\mu}d_{t})$ $(\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t})$	$egin{array}{c} \mathcal{O}_{le} & & \ \mathcal{O}_{lu} & & \ \mathcal{O}_{ld} & & \ \mathcal{O}_{qe} & & \ \mathcal{O}_{qu}^{(1)} & & \ \end{array}$	$(\bar{L}L)(\bar{R}R)$ $(\bar{l}_p\gamma_{\mu}l_r)(\bar{e}_s\gamma^{\mu}e_t)$ $(\bar{l}_p\gamma_{\mu}l_r)(\bar{u}_s\gamma^{\mu}u_t)$ $(\bar{l}_p\gamma_{\mu}l_r)(\bar{d}_s\gamma^{\mu}d_t)$ $(\bar{q}_p\gamma_{\mu}q_r)(\bar{e}_s\gamma^{\mu}e_t)$ $(\bar{q}_p\gamma_{\mu}q_r)(\bar{u}_s\gamma^{\mu}u_t)$	
$\begin{array}{ c c }\hline & \mathcal{O}_{ll} \\ & \mathcal{O}_{qq}^{(1)} \\ & \mathcal{O}_{qq}^{(3)} \\ & \mathcal{O}_{lq}^{(1)} \\ & \mathcal{O}_{lq}^{(3)} \\ & \mathcal{O}_{lq}^{(3)} \end{array}$	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{l}_{s}\gamma^{\mu}l_{t})$ $(\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{q}_{s}\gamma^{\mu}q_{t})$ $(\bar{q}_{p}\gamma_{\mu}\tau^{I}q_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t})$ $(\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{q}_{s}\gamma^{\mu}q_{t})$ $(\bar{l}_{p}\gamma_{\mu}\tau^{I}l_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t})$	$\mathcal{O}_{ee}$ $\mathcal{O}_{uu}$ $\mathcal{O}_{dd}$ $\mathcal{O}_{eu}$ $\mathcal{O}_{ed}$ $\mathcal{O}_{ud}^{(1)}$	$\begin{array}{c} (\bar{R}R)(\bar{R}R) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{d}_{p}\gamma_{\mu}d_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \end{array}$	$egin{array}{c} \mathcal{O}_{le} & & \ \mathcal{O}_{lu} & & \ \mathcal{O}_{ld} & & \ \mathcal{O}_{qe} & & \ \mathcal{O}_{qu}^{(1)} & & \ \mathcal{O}_{qu}^{(8)} & \ $	$\begin{array}{c} (\bar{L}L)(\bar{R}R) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \end{array}$	
$\begin{array}{ c c c c c }\hline & & & & \\ & & & & \\ & & & & \\ & & & & $	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$ $(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$ $(\bar{q}_p\gamma_\mu \tau^I q_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{q}_s\gamma^\mu q_t)$ $(\bar{l}_p\gamma_\mu \tau^I l_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$	$\mathcal{O}_{ee}$ $\mathcal{O}_{uu}$ $\mathcal{O}_{dd}$ $\mathcal{O}_{eu}$ $\mathcal{O}_{ed}$ $\mathcal{O}_{ud}$ $\mathcal{O}_{ud}^{(1)}$ $\mathcal{O}_{ud}^{(8)}$	$\begin{array}{c} (\bar{R}R)(\bar{R}R) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{d}_{p}\gamma_{\mu}d_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}T^{A}u_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array}$	$\mathcal{O}_{le}$ $\mathcal{O}_{lu}$ $\mathcal{O}_{ld}$ $\mathcal{O}_{qe}$ $\mathcal{O}_{qu}^{(1)}$ $\mathcal{O}_{qu}^{(8)}$ $\mathcal{O}_{qd}^{(1)}$	$\begin{array}{c} (\bar{L}L)(\bar{R}R) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \end{array}$	
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$O_{ll}$ $O_{qq}$ $O_{qq}^{(1)}$ $O_{lq}^{(3)}$ $O_{lq}^{(3)}$ $O_{lq}^{(3)}$	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{l}_{s}\gamma^{\mu}l_{t})$ $(\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{q}_{s}\gamma^{\mu}q_{t})$ $(\bar{q}_{p}\gamma_{\mu}\tau^{I}q_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t})$ $(\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{q}_{s}\gamma^{\mu}q_{t})$ $(\bar{l}_{p}\gamma_{\mu}\tau^{I}l_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t})$ $(\bar{R}L) \text{ and } (\bar{L}R)(\bar{L}R)$	$\mathcal{O}_{ee}$ $\mathcal{O}_{uu}$ $\mathcal{O}_{dd}$ $\mathcal{O}_{eu}$ $\mathcal{O}_{ed}$ $\mathcal{O}_{ud}^{(1)}$ $\mathcal{O}_{ud}^{(8)}$	$ \begin{array}{c} (\bar{R}R)(\bar{R}R) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{d}_{p}\gamma_{\mu}d_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{u}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}T^{A}u_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array} \\ \end{array} $	$\begin{matrix} \mathcal{O}_{le} \\ \mathcal{O}_{lu} \\ \mathcal{O}_{ld} \\ \mathcal{O}_{qe} \\ \mathcal{O}_{qu}^{(1)} \\ \mathcal{O}_{qu}^{(8)} \\ \mathcal{O}_{qd}^{(1)} \\ \mathcal{O}_{qd}^{(8)} \\ \mathcal{O}_{qd}^{(8)} \end{matrix}$	$\begin{array}{c} (\bar{L}L)(\bar{R}R) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array}$	
$\begin{array}{ c c c c }\hline & \mathcal{O}_{ll} & & \\ & \mathcal{O}_{qq}^{(1)} & & \\ & \mathcal{O}_{lq}^{(3)} & & \\ & \mathcal{O}_{lq}^{(3)} & & \\ & \mathcal{O}_{lq}^{(3)} & & \\ & & \mathcal{O}_{lq}^{(3)} & \\ & & & \\ \hline & & & \\ & & & & \\ \hline & & & &$	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{l}_{s}\gamma^{\mu}l_{t})$ $(\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{q}_{s}\gamma^{\mu}q_{t})$ $(\bar{q}_{p}\gamma_{\mu}\tau^{I}q_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t})$ $(\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{q}_{s}\gamma^{\mu}q_{t})$ $(\bar{l}_{p}\gamma_{\mu}\tau^{I}l_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t})$ $(\bar{k}L) \text{ and } (\bar{L}R)(\bar{L}R)$ $(\bar{l}_{p}^{j}e_{r})(\bar{d}_{s}q_{t}^{j})$	$\mathcal{O}_{ee}$ $\mathcal{O}_{uu}$ $\mathcal{O}_{dd}$ $\mathcal{O}_{eu}$ $\mathcal{O}_{ed}$ $\mathcal{O}_{ud}^{(1)}$ $\mathcal{O}_{ud}^{(8)}$ $\mathcal{O}_{ud}$	$ \begin{array}{c} (\bar{R}R)(\bar{R}R) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{d}_{p}\gamma_{\mu}d_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{u}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}T^{A}u_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array} $	$\left[egin{array}{c} \mathcal{O}_{le} & & \ \mathcal{O}_{lu} & & \ \mathcal{O}_{ld} & & \ \mathcal{O}_{qe} & & \ \mathcal{O}_{qu}^{(1)} & & \ \mathcal{O}_{qd}^{(1)} & & \ \mathcal{O}_{qd}^{(8)} & & \ \mathcal{O}$	$ \begin{array}{c} (\bar{L}L)(\bar{R}R) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array} $	
$\begin{array}{c c} & \mathcal{O}_{ll} \\ & \mathcal{O}_{qq}^{(1)} \\ & \mathcal{O}_{lq}^{(3)} \\ & \mathcal{O}_{lq}^{(3)} \\ & \mathcal{O}_{lq}^{(3)} \\ & \mathcal{O}_{lq}^{(3)} \\ \\ & \mathcal{O}_{lq}^{(3)} \\ \\ & \mathcal{O}_{lq}^{(1)} \\ & \mathcal{O}_{ledq}^{(1)} \\ & \mathcal{O}_{quqd}^{(1)} \end{array}$	$\frac{\mu\nu}{(\bar{L}L)(\bar{L}L)}$ $(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$ $(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$ $(\bar{q}_p\gamma_\mu \tau^I q_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$ $(\bar{l}_p\gamma_\mu l_r)(\bar{q}_s\gamma^\mu q_t)$ $(\bar{l}_p\gamma_\mu \tau^I l_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$ $(\bar{l}_p^j \mu_\tau \tau^I l_r)(\bar{q}_s\gamma^\mu \tau^I q_t)$ $(\bar{l}_p^j \mu_\tau r^J l_r)(\bar{d}_s q_t^j)$ $(\bar{q}_p^j u_r)\varepsilon_{jk}(\bar{q}_s^k d_t)$	$\mathcal{O}_{ee}$ $\mathcal{O}_{uu}$ $\mathcal{O}_{dd}$ $\mathcal{O}_{eu}$ $\mathcal{O}_{ed}$ $\mathcal{O}_{ud}$ $\mathcal{O}_{ud}^{(8)}$ $\mathcal{O}_{ud}$	$\begin{array}{c} (\bar{R}R)(\bar{R}R) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{d}_{p}\gamma_{\mu}d_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}T^{A}u_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array}$ $\begin{array}{c} B\text{-viol} \\ \hline \varepsilon^{\alpha\beta\gamma}\varepsilon_{jk} \left[ (d_{p}^{\alpha}) \\ \varepsilon^{\alpha\beta\gamma}\varepsilon_{jk} \right] \\ (\bar{u}_{p}^{\alpha}) \\ \end{array}$	$\left[egin{array}{c} \mathcal{O}_{le} & & \ \mathcal{O}_{lu} & & \ \mathcal{O}_{ld} & & \ \mathcal{O}_{qu} & & \ \mathcal{O}_{qu} & & \ \mathcal{O}_{qu}^{(1)} & & \ \mathcal{O}_{qd}^{(8)} & & \ \mathcal{O}_{qd}^{(1)} & & \ \mathcal{O}_{qd}^{(8)} & \ \mathcal{O}_{qd}^{(8)} & & \ \mathcal{O}_{qd}^{(8)} & \ \mathcal{O}_{qd}^{(8)} & & \ \mathcal{O}_{qd}^{(1)} & & \ \mathcal{O}_{qd}^{(8)} & \ \mathcal{O}_{qd}^{(1)} & & \ \mathcal{O}_{qd}^{(1)} $	$\begin{array}{c} (\bar{L}L)(\bar{R}R) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array}$	
$ \begin{array}{c c} \mathcal{O}_{ll} \\ \mathcal{O}_{qq}^{(1)} \\ \mathcal{O}_{qq}^{(3)} \\ \mathcal{O}_{lq}^{(3)} \\ \mathcal{O}_{lq}^{(3)} \\ \mathcal{O}_{lq}^{(3)} \\ \end{array} \\ \hline \begin{array}{c} (\bar{L}R) \\ \mathcal{O}_{ledq} \\ \mathcal{O}_{quqd}^{(1)} \\ \mathcal{O}_{quqd}^{(8)} \\ \mathcal{O}_{quqd}^{(8)} \end{array} \end{array} $	$ \frac{\mu\nu}{(\bar{L}L)(\bar{L}L)} \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{l}_{s}\gamma^{\mu}l_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{q}_{s}\gamma^{\mu}q_{t}) \\ (\bar{q}_{p}\gamma_{\mu}\tau^{I}q_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{q}_{s}\gamma^{\mu}q_{t}) \\ (\bar{l}_{p}\gamma_{\mu}\tau^{I}l_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t}) \\ (\bar{l}_{p}p_{\mu}\tau^{I}l_{r})(\bar{q}_{s}\gamma^{\mu}\tau^{I}q_{t}) \\ \hline (\bar{l}_{p}p_{\mu}\tau^{I}l_{r})(\bar{q}_{s}q_{t}^{\mu}\tau^{I}q_{t}) \\ (\bar{q}_{p}^{j}u_{r})\varepsilon_{jk}(\bar{q}_{s}^{k}d_{t}) \\ (\bar{q}_{p}^{j}T^{A}u_{r})\varepsilon_{jk}(\bar{q}_{s}^{k}T^{A}d_{t}) \\ \hline \end{array} $	$\mathcal{O}_{ee}$ $\mathcal{O}_{uu}$ $\mathcal{O}_{dd}$ $\mathcal{O}_{eu}$ $\mathcal{O}_{ed}$ $\mathcal{O}_{ud}$ $\mathcal{O}_{ud}$ $\mathcal{O}_{ud}$ $\mathcal{O}_{ud}$	$ \begin{array}{c} (\bar{R}R)(\bar{R}R) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{d}_{p}\gamma_{\mu}d_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{u}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}T^{A}u_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array} $	$\left[egin{array}{c} \mathcal{O}_{le} & & \ \mathcal{O}_{lu} & & \ \mathcal{O}_{ld} & & \ \mathcal{O}_{qe} & & \ \mathcal{O}_{qu} & & \ \mathcal{O}_{qu}^{(1)} & & \ \mathcal{O}_{qd}^{(8)} & & \ \mathcal{O}_{qd}^{(1)} & & \ \mathcal{O}_{qd}^{(1)} & & \ \mathcal{O}_{qd}^{(2)} & & \ \mathcal{O}_{qd}^{(3)} & & \ \mathcal{O}_{qd}^$	$ \begin{array}{c} (\bar{L}L)(\bar{R}R) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array} $	
$ \begin{array}{c c} \mathcal{O}_{ll} \\ \mathcal{O}_{qq} \\ \mathcal{O}_{qq}^{(1)} \\ \mathcal{O}_{lq}^{(2)} \\ \mathcal{O}_{lq}^{(3)} \\ \mathcal{O}_{lq}^{(3)} \\ \mathcal{O}_{lq}^{(3)} \\ \end{array} \\ \hline \begin{array}{c} (\bar{L}R) \\ \mathcal{O}_{ledq} \\ \mathcal{O}_{quqd}^{(1)} \\ \mathcal{O}_{quqd}^{(1)} \\ \mathcal{O}_{lequ}^{(1)} \\ \mathcal{O}_{lequ}^{(1)} \\ \end{array} \\ \end{array} $	$ \begin{array}{c} \underline{\mu\nu} \\ \hline (\bar{L}L)(\bar{L}L) \\ (\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t) \\ (\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t) \\ (\bar{q}_p\gamma_\mu \tau^I q_r)(\bar{q}_s\gamma^\mu \tau^I q_t) \\ (\bar{l}_p\gamma_\mu l_r)(\bar{q}_s\gamma^\mu q_t) \\ (\bar{l}_p\gamma_\mu \tau^I l_r)(\bar{q}_s\gamma^\mu \tau^I q_t) \\ \end{array} \\ \hline (\bar{l}_p\gamma_\mu \tau^I l_r)(\bar{q}_s\gamma^\mu \tau^I q_t) \\ \hline (\bar{l}_p^j e_r)(\bar{d}_s q_t^j) \\ (\bar{q}_p^j u_r) \varepsilon_{jk}(\bar{q}_s^k d_t) \\ (\bar{q}_p^j T^A u_r) \varepsilon_{jk}(\bar{q}_s^k T^A d_t) \\ (\bar{l}_p^j e_r) \varepsilon_{jk}(\bar{q}_s^k u_t) \\ \hline \end{array} $	$\begin{array}{c} & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & $	$\begin{array}{c} (\bar{R}R)(\bar{R}R) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{d}_{p}\gamma_{\mu}d_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{e}_{p}\gamma_{\mu}e_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}u_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{u}_{p}\gamma_{\mu}T^{A}u_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array}$	$\begin{matrix} \mathcal{O}_{le} \\ \mathcal{O}_{lu} \\ \mathcal{O}_{ld} \\ \mathcal{O}_{qe} \\ \mathcal{O}_{qu}^{(1)} \\ \mathcal{O}_{qd}^{(2)} \\ \mathcal{O}_{qd}^{(3)} \\ \mathcal{O}_{qd}^{(3)$	$\begin{array}{c} (\bar{L}L)(\bar{R}R) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{u}_{s}\gamma^{\mu}u_{t}) \\ (\bar{l}_{p}\gamma_{\mu}l_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{e}_{s}\gamma^{\mu}e_{t}) \\ (\bar{q}_{p}\gamma_{\mu}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{u}_{s}\gamma^{\mu}T^{A}u_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}d_{t}) \\ (\bar{q}_{p}\gamma_{\mu}T^{A}q_{r})(\bar{d}_{s}\gamma^{\mu}T^{A}d_{t}) \end{array}$	

## A global fit to the SMEFT

Each operator contributes to multiple datasets

expect an interplay between sectors



## A global fit to the SMEFT

This highlights the need for a **global fit** to understand and parameterise the deviations and correlations between operators and sectors.

We include data from top, diboson, Higgs and EWPO in a fit to 34 dim-6 operators.



## SMEFT conventions

- Warsaw basis
- Neglect CP-violating operators
- Two flavour scenarios:

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{i} \frac{C_i}{\Lambda^2} \mathcal{O}_i$$

- Flavour universal  $SU(3)^5$
- Top-specific flavour scenario singles out top couplings [1802.07237]  $SU(3)^5 \rightarrow SU(2)_q \times SU(2)_u \times SU(3)_d \times SU(3)_l \times SU(3)_e$

In both flavour scenarios we also include 4 Yukawa operators which explicitly break these flavour symmetries:

$$\mathcal{O}_{ au H}, \mathcal{O}_{\mu H}, \mathcal{O}_{b H}, \mathcal{O}_{t H}$$

## Measurements

- 341 statistically independent measurements
- Correlation information included from published covariance matrices

#### Higgs: 72

- Signal strength combinations (LHC Run 1 and Run 2)
- STXS combination (LHC Run 2)
- Measurements of

 $H \to Z\gamma \qquad H \to \mu\mu$ 

## Higgs STXS data from LHC Run 2 ATLAS

#### ATLAS Run 2 STXS combination [HIGG-2018-57, Phys. Rev. D 101 (2020) 012002]

A total of 21 STXS bins with published correlation matrix

ATLAS $\sqrt{s} = 13 \text{ TeV}, 33$ $m_H = 125.09 \text{ G}$ $p_{SM} = 69\%$ 1  Total	86.1 - 79.8 fb <sup>-1</sup> GeV,  y <sub>H</sub>   < 2.5	B <sub>γγ</sub> /B <sub>ZZ</sub> , B <sub>bb</sub> /B <sub>ZZ</sub> , B <sub>WW</sub> ,B <sub>ZZ</sub> , B <sub>τ</sub> (B <sub>ZZ</sub> ,			0.81 0.61 0.93 0.78	Total Stat. +0.14 (+0.12 -0.12 (-0.10) +0.39 (+0.24) -0.29 (-0.18) +0.20 (+0.14) -0.17 (-0.12) +0.29 (+0.22) -0.23 (-0.18)	Syst. +0.07 -0.06) +0.32 -0.22) +0.14 -0.12) +0.19 -0.14)
Syst.	I SM	0	0.5	1	1.5	2 Tatal Ctat	2.5
gg→H × B <sub>ZZ*</sub>	0-jet 1-jet, $p_{T}^{H} < 60 \text{ GeV}$ 1-jet, $60 \le p_{T}^{H} < 124$ 1-jet, $120 \le p_{T}^{H} < 20$ 1-jet, $p_{T}^{H} \ge 200 \text{ GeV}$ $\ge 2$ -jet, $p_{T}^{H} < 60 \text{ Ge}$ $\ge 2$ -jet, $60 \le p_{T}^{H} < 1$ $\ge 2$ -jet, $120 \le p_{T}^{H} < 200 \text{ GeV}$ $\ge 2$ -jet, $p_{T}^{H} \ge 200 \text{ GeV}$ $\ge 2$ -jet, $p_{T}^{H} \ge 200 \text{ GeV}$ $\ge 2$ -jet, $p_{T}^{H} \ge 200 \text{ GeV}$	0 GeV 00 GeV V E 20 GeV 200 GeV eV			1.30 1.16 1.36 2.39 1.52 0.71 2.12 1.21 3.19 H6.90	$\begin{array}{c ccccc} \text{rotal} & \text{Stat.} \\ +0.19 & (+0.16) \\ -0.18 & (-0.15) \\ \pm0.55 & (+0.47) \\ \pm0.55 & (+0.47) \\ \pm0.56 & (+0.51) \\ -0.56 & (+0.51) \\ -0.56 & (+0.51) \\ -0.99 & (-0.48) \\ \pm1.30 & (+1.19) \\ -1.17 & (-1.09) \\ \pm1.26 & (\pm1.17) \\ -1.17 & (-1.05) \\ \pm1.21 & (+0.97) \\ -0.97 & (-0.89) \\ \pm1.26 & (-1.12) \\ -1.08 & (+1.12) \\ -1.08 & (+1.22) \\ -1.08 & (+1.22) \\ -1.08 & (\pm1.22) \\ -2.55 & (-2.16) \\ \end{array}$	\$     Syst.     ±0.10)     +0.28     -0.30)     +0.32     -0.28)     +0.52     -0.46)     +0.53     -0.44)     +1.23     -0.79)     +0.60     -0.50)     +0.58     -0.39)     +0.58     -0.46)     +1.84     -1.37
qq→Hqq × B <sub>ZZ*</sub>	VBF topo VH topo Rest H $p_{\tau}^{i} \ge 200 \text{ GeV}$	ا دی۔ ا <del>ر دی۔</del> ا <del>ر دی</del> ۔			0.92 -0.34 -2.70 -1.67	$ \begin{array}{c} +0.57 \\ -0.52 \\ +1.53 \\ +1.53 \\ +1.30 \\ +2.97 \\ +2.97 \\ +2.42 \\ -2.42 \\ -1.81 \\ -1.55 \end{array} $	+0.30 -0.27) +0.42 -0.35) +1.74 -1.26) +0.88 -0.93)
$qq \rightarrow Hlv \times B_{ZZ^*}$	$p_{\tau}^{V} < 150 \text{ GeV}$ $150 \le p_{\tau}^{V} < 250 \text{ GeV}$ $p_{\tau}^{V} \ge 250 \text{ GeV}$	۶V			2.57 2.20 1.99	$ \begin{array}{c} ^{+1.81}_{-1.60} \left(\begin{smallmatrix} ^{+1.67}_{-1.49} \\ ^{+2.23}_{-1.51} \left(\begin{smallmatrix} ^{+1.57}_{-1.19} \\ ^{+2.48}_{-1.24} \right) \\ ^{+1.49}_{-1.04} \end{array} \right) $	+0.68 -0.59) +1.58 -0.93) +1.98 -0.66)
gg/qq→Hll × B <sub>zz*</sub>	$p_{\tau}^{V} < 150 \text{ GeV}$ $150 \le p_{\tau}^{V} < 250 \text{ Ge}$ $p_{\tau}^{V} \ge 250 \text{ GeV}$	F <del>⊂</del> V F		<b>⇒</b> -1	0.89 0.90 2.99	$ \begin{array}{c} +1.31\\ -1.68\\ +1.37\\ +1.37\\ -1.18\\ +3.44\\ +2.03\\ -1.60\\ -1.39 \end{array} $	+0.79 -1.34) +0.87 -0.74) +2.79 -0.80
$(t\overline{t}H + tH) \times B_{ZZ^*}$		1		1	1.48	+0.40 (+0.31 -0.34 (-0.28	+0.25 -0.20)
	-10 -{	5 0		5	10	15	20
	Parameter	normalize	ed to S	M value	ć		



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#### Higgs: 72

- Signal strength combinations (LHC Run 1 and Run 2)
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#### Diboson: 118

• LHC and LEP measurements of

WW, WZ, Zjj

#### EWPO: 14

LEP, Tevatron, LHC measurements

 $\{\Gamma_{Z}, \sigma_{\text{had.}}^{0}, R_{l}^{0}, A_{FB}^{l}, A_{l}, R_{b}^{0}, R_{c}^{0}, A_{FB}^{b}, A_{FB}^{c}, A_{FB}^{c}, A_{b}, A_{c}, M_{W}\}.$ 

#### Тор: 137

LHC measurements of

 $t\bar{t}, t\bar{t}+V, \text{ single top}$ 

$$\chi^2(C_i) = (\vec{y} - \vec{\mu}(C_i))^T V^{-1}(\vec{y} - \vec{\mu}(C_i))$$

 $ec{y}$ : vector of observables with covariance matrix V

Predictions: 
$$\mu_{\alpha}(C_i) = \mu_{\alpha}^{SM} + H_{\alpha i}C_i$$
  
i.e. restricting to  $\mathcal{O}(\Lambda^{-2})$  in the EFT expansion

Best-fit WC: 
$$\hat{\vec{C}} = (H^T V^{-1} H)^{-1} H^T V^{-1} (\vec{y} - \vec{\mu}^{SM})$$
  
Covariance:  $U = (H^T V^{-1} H)^{-1} = F^{-1}$ 

(Fisher information)

#### Fit to Higgs, diboson, electroweak data in the flavour universal scenario:



## STXS measurements for ggF

STXS measurements of gluon gluon fusion **improve sensitivity** and **break degeneracy** between SMEFT operators:





## **Top-Higgs interplay**

Studying the interplay of Higgs and top data in constraining the operators  $\mathcal{O}_{tH}, \mathcal{O}_{tG}, \mathcal{O}_{G}, \mathcal{O}_{HG}$ 15 10 5 C<sub>tH</sub> while marginalising over -5 -10 $\mathcal{O}_{H\square}, \mathcal{O}_{HW}, \mathcal{O}_{HB}, \mathcal{O}_{bH}, \mathcal{O}_{\tau H}, \mathcal{O}_{\mu H}$  (+4F operators) -15-20 -0.04 -0.02 0.00 0.02 0.04 1  $C_{tG}$ -2 Marginalised 95% C. L. -40.04 - 0.02 0.00 0.02 0.04-20 - 15 - 10-5: 0 +5 Higgs data (no *t*t*H*) Higgs data 10 10 Higgs & Top data  $C_{G}$ 0 Higgs & Top data (+4F) -5 SM -10-10 -20-15-10-5 0 5 10 15 0.02 0.04 -4 -3 -2 -0.040.00 1 2 J CtH  $C_{HG}$ CtG

15

## Principal Component Analysis



## UV models

We analyse our fit in terms of a set of BSM benchmark models from *2009.01249 Marzocca et. al, 1711.10391 de Blas et. al* 

Name	Spin	SU(3)	SU(2)	U(1)	Name	Spin	SU(3)	SU(2)	U(1)
S	0	1	1	0	$\Delta_1$	$\frac{1}{2}$	1	2	$-\frac{1}{2}$
$S_1$	0	1	1	1	$\Delta_3$	$\frac{1}{2}$	1	2	$-\frac{1}{2}$
arphi	0	1	2	$\frac{1}{2}$	$\Sigma$	$\frac{1}{2}$	1	3	0
[I]	0	1	3	0	$\Sigma_1$	$\frac{1}{2}$	1	3	-1
<b>Ξ</b> 1	0	1	3	1	U	$\frac{1}{2}$	3	1	$\frac{2}{3}$
B	1	1	1	0	D	$\frac{1}{2}$	3	1	$-\frac{1}{3}$
$B_1$	1	1	1	1	$Q_1$	$\frac{1}{2}$	3	2	$\frac{1}{6}$
W	1	1	3	0	$Q_5$	$\frac{1}{2}$	3	2	$-\frac{5}{6}$
$W_1$	1	1	3	1	$Q_7$	$\frac{1}{2}$	3	2	$\frac{7}{6}$
N	$\frac{1}{2}$	1	1	0	$T_1$	$\frac{1}{2}$	3	3	$-\frac{1}{3}$
E	$\frac{1}{2}$	1	1	-1	$T_2$	$\frac{1}{2}$	3	3	$\frac{2}{3}$
T	$\frac{1}{2}$	3	1	$\frac{2}{3}$	TB	$\frac{1}{2}$	3	2	$\frac{1}{6}$

## UV models: patterns

We analyse our fit in terms of a set of BSM benchmark models from *2009.01249 Marzocca et. al, 1711.10391 de Blas et. al* 

Some models exhibit similar patterns among operators

- Consider models with couplings to leptons:  $N, E, \Delta_1, \Delta_3, \Sigma, \Sigma_1$
- These will generate

$$\mathcal{O}_{Hl}^{(1)}, \mathcal{O}_{Hl}^{(3)}, \mathcal{O}_{He}, \mathcal{O}_{ll}$$

with patterns such as  $C_{Hl}^{(1)} \propto C_{Hl}^{(3)}$  and  $C_{ll} \propto C_{He}$ 

## UV models: patterns



See 2012.02779 for quark-specific, top-specific and boson-specific cases

# Conclusions

Global fit produced using Fitmaker:

a publicly available python code <u>https://gitlab.com/kenmimasu/fitrepo</u> (Version for public use still to come!)

 an adaptable, flexible and extensible framework for performing global SMEFT fits.

## **Thank you for listening!**

# Backup

### Datasets: Higgs

LHC Run 1 Higgs	$n_{\mathbf{obs}}$	Ref.
ATLAS and CMS LHC Run 1 combination of Higgs signal strengths.	21	[8]
Production: $ggF$ , $VBF$ , $ZH$ , $WH$ & $ttH$		
Decay: $\gamma\gamma$ , ZZ, $W^+W^-$ , $\tau^+\tau^-$ & $b\overline{b}$		
ATLAS inclusive $Z\gamma$ signal strength measurement	1	9
LHC Run 2 Higgs (new)	$n_{\mathbf{obs}}$	Ref.
ATLAS combination of signal strengths and stage 1.0 STXS in $H \to 4\ell$	16 19 25	[10]
including ratios of branching fractions to $\gamma\gamma$ , $WW^*$ , $\tau^+\tau^-$ & $b\bar{b}$		
Signal strengths coarse STXS bins fine STXS bins		
CMS LHC combination of Higgs signal strengths.	23	[11]
Production: $ggF$ , $VBF$ , $ZH$ , $WH$ & $ttH$		
Decay: $\gamma\gamma$ , ZZ, W <sup>+</sup> W <sup>-</sup> , $\tau^+\tau^-$ , $b\overline{b}$ & $\mu^+\mu^-$		
CMS stage 1.0 STXS measurements for $H \to \gamma \gamma$ .	13 7	[12]
13 parameter fit   7 parameter fit		
CMS stage 1.0 STXS measurements for $H \to \tau^+ \tau^-$	9	[13]
CMS stage 1.1 STXS measurements for $H \to 4\ell$	19	[14]
CMS differential cross section measurements of inclusive Higgs produc-	5 6	[15]
tion in the $WW^* \to \ell \nu \ell \nu$ final state.		
$\frac{d\sigma}{dn_{\rm jet}} \mid \frac{d\sigma}{dp_H^T}$		
ATLAS $H \to Z\gamma$ signal strength.	1	[16]
ATLAS $H \to \mu^+ \mu^-$ signal strength.	1	[17]

EW precision observables	$n_{\mathbf{obs}}$	Ref.
Precision electroweak measurements on the $Z$ resonance.	12	[1]
$\Gamma_Z, \sigma_{\text{had.}}^0, R_\ell^0, A_{FB}^\ell, A_\ell(\text{SLD}), A_\ell(\text{Pt}), R_b^0, R_c^0, A_{FB}^b, A_{FB}^c, A_b \& A_c$		
Combination of CDF and D0 W-Boson Mass Measurements	1	[6]
LHC run 1 W boson mass measurement by ATLAS	1	[57]
Diboson LEP & LHC	$n_{\mathbf{obs}}$	Ref.
$W^+W^-$ angular distribution measurements at LEP II.	8	[5]
$W^+ W^-$ total cross section measurements at L3 in the $\ell \nu \ell \nu$ , $\ell \nu qq \& qq qq$	24	[3]
final states for 8 energies		
$W^+W^-$ total cross section measurements at OPAL in the $\ell\nu\ell\nu$ , $\ell\nu qq$ &	21	[4]
qqqq final states for 7 energies		
$W^+W^-$ total cross section measurements at ALEPH in the $\ell\nu\ell\nu$ , $\ell\nu qq$	21	[2]
& $qqqq$ final states for 8 energies		
ATLAS $W^+W^-$ differential cross section in the $e\nu\mu\nu$ channel, $\frac{d\sigma}{dp_{\ell_*}^T}$ ,	1	[66]
$p_T > 120 \text{ GeV}$ overflow bin		
ATLAS $W^+W^-$ fiducial differential cross section in the $e\nu\mu\nu$ channel,	14	[70]
$rac{d\sigma}{dp_{\ell_1}^T}$		
ATLAS $W^{\pm} Z$ fiducial differential cross section in the $\ell^+ \ell^- \ell^{\pm} \nu$ channel,	7	[69]
$\frac{d\sigma}{dp_Z^T}$		
CMS $W^{\pm} Z$ normalised fiducial differential cross section in the $\ell^+ \ell^- \ell^{\pm} \nu$	11	[67]
channel, $\frac{1}{\sigma} \frac{d\sigma}{dp_Z^T}$		
ATLAS $Zjj$ fiducial differential cross section in the $\ell^+\ell^-$ channel, $\frac{d\sigma}{d\Delta\varphi_{jj}}$	12	[71]

#### Datasets: top

Tevatron & Run 1 top	$n_{\mathbf{obs}}$	Ref.
Tevatron combination of differential $t\bar{t}$ forward-backward asymmetry,	4	[7]
$A_{FB}(m_{t\bar{t}}).$		
ATLAS $t\bar{t}$ differential distributions in the dilepton channel.	6	[18]
$rac{d\sigma}{dm_{tar{t}}}$		
ATLAS $t\bar{t}$ differential distributions in the $\ell$ +jets channel.	7 5 8 5	[19]
$\left  rac{d\sigma}{dm_{tar{t}}}  ight  \left  rac{d\sigma}{d y_{tar{t}} }  ight  \left  rac{d\sigma}{dp_t^T}  ight  \left  rac{d\sigma}{d y_t }  ight .$		
CMS $t\bar{t}$ differential distributions in the $\ell$ +jets channel.	7 10 8  10	[20,
$\left  rac{d\sigma}{dm_{tar{t}}}  ight  \left  rac{d\sigma}{dy_{tar{t}}}  ight  \left  rac{d\sigma}{dp_t^T}  ight  \left  rac{d\sigma}{dy_t}  ight .$		215]
CMS measurement of differential $t\bar{t}$ charge asymmetry, $A_C(m_{t\bar{t}})$ in the	3	
dilepton channel.		[216]
ATLAS inclusive measurement $t\bar{t}$ charge asymmetry, $A_C(m_{t\bar{t}})$ in the	1	
dilepton channel.		[217]
ATLAS & CMS combination of differential $t\bar{t}$ charge asymmetry,	6	[21]
$A_C(m_{t\bar{t}})$ , in the $\ell$ +jets channel.		
CMS $t\bar{t}$ double differential distributions in the dilepton channel.	16 16	[22,
$\left  rac{d\sigma}{dm_{tar{t}}dy_t}  ight  \left  rac{d\sigma}{dm_{tar{t}}dy_{tar{t}}}  ight  \left  rac{d\sigma}{dm_{tar{t}}dp_{tar{t}}^T}  ight  \left  rac{d\sigma}{dy_t dp_t^T}  ight .$	16 16	218]
ATLAS & CMS Run 1 combination of $W$ -boson helicity fractions in top	3	[23]
decay. $f_0, f_L \& f_R$		
ATLAS measurement of $W$ -boson helicity fractions in top decay.	3	[24]
$f_0, f_L \& f_R$		
CMS measurement of $W$ -boson helicity fractions in top decay.	3	[25]
$f_0,f_L\&f_R$		
ATLAS $t\bar{t}W$ & $t\bar{t}Z$ cross section measurements. $\sigma_{t\bar{t}W} \sigma_{t\bar{t}Z}$	2	[26]
CMS $t\bar{t}W$ & $t\bar{t}Z$ cross section measurements. $\sigma_{t\bar{t}W} \sigma_{t\bar{t}Z}$	2	[27]
ATLAS <i>t</i> -channel single-top differential distributions.	4 4 4 5	[28]
$\left  rac{d\sigma}{dp_t^T} ~ \left  ~ rac{d\sigma}{dp_{ar t}^T} ~ \left  ~ rac{d\sigma}{d y_t } ~ \left  ~ rac{d\sigma}{d y_{ar t} }  ight   ight.$		
CMS $s$ -channel single-top cross section measurement.	1	[29]
CMS $t$ -channel single-top differential distributions.	6   6	[30]
$\left  rac{d\sigma}{dp_{\star \perp ar{t}}^T}  ight  = rac{d\sigma}{d y_{t+ar{t}} }$		
CMS measurement of the <i>t</i> -channel single-top and anti-top cross sections.	1 1 1 1	[31]
$\sigma_t     \sigma_{\overline{t}}     \sigma_{t+\overline{t}}     R_t.$		
ATLAS <i>s</i> -channel single-top cross section measurement.	1	[32]
CMS $tW$ cross section measurement.	1	[33]
ATLAS $tW$ cross section measurement in the single lepton channel.	1	[34]
ATLAS $tW$ cross section measurement in the dilepton channel.	1	[35]